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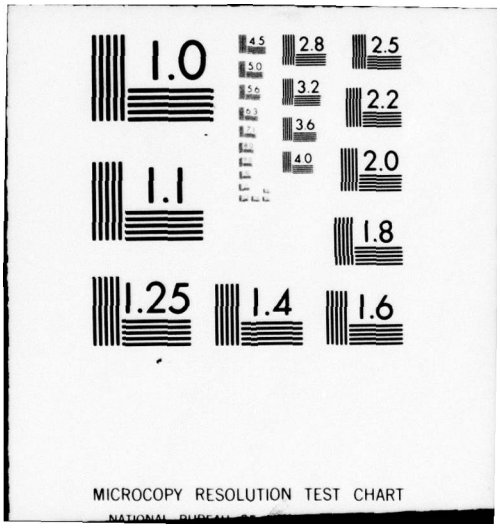
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CAYWOOD-SCHILLER DIVISION
A. T. KEARNEY, INC.
100 South Wacker Drive
Chicago, Illinois 60606

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PACAM IV

MULTIPLE AIRCRAFT THREE DIMENSIONAL AIR-TO-AIR COMBAT.

ANALYST'S MANUAL.

(An Addendum to the PACAM II Analyst's Manual)

(10) Michael A./Dloogatch
Donald H./Schiller

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PACAM IV is a model developed to help evaluate air-to-air armaments by simulating performance of aircraft and weapons in air-to-air combat. The model treats 1v1 or 2v1 combats at the user's option. The tactics used include a series of fighter and bomber penetration tactics. The program features dynamic weapon firing of missiles, lasers and guns, including aircraft reatction to being fired upon. Integral kill evaluation is included. The model is programmed FORTRAN IV for the CDC 6600.

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TABLE OF CONTENTS

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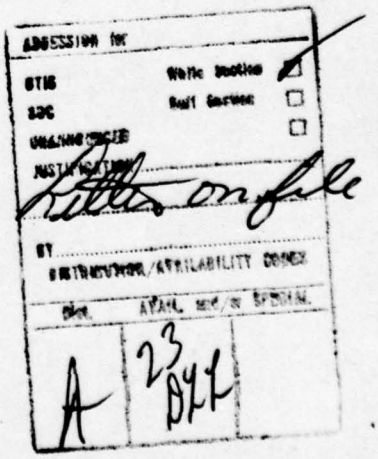

SECTION 1

BACKGROUND

PACAM iv is a computer model, developed to assist in the evaluation of air-to-air armaments by simulating the performance of aircraft and weapons in aerial combat. It has been developed from a prior version (PACAM II) as discussed in Section 2 below. The PACAM II Analyst's Manual [1] presents the equations, assumptions and details required by an analyst to understand and assess the model output. *This present volume will not repeat these derivations and assumptions, but will be limited to a description of the changes, additions and deletions necessary to the development of PACAM IV. For this reason, this volume should be considered as an addendum to the PACAM II manual, and used in conjuction with it.* A companion report, the PACAM IV User's Manual is intended to provide sufficient information for an analyst to collect and enter all data necessary for successful computer operations of the PACAM IV model.

Section 2 below describes the model structure briefly, and includes a discussion of the features available in the present version. Section 3 present the details of the required program changes, focusing on subroutines which have been added, modified or deleted in the process of developing PACAM IV from PACAM II.

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(1) CAYWOOD-SCHILLER DIVISION, A. T. KEARNEY, INC.
PACAM II, MULTIPLE AIRCRAFT THREE DIMENSIONAL AIR-TO-AIR COMBAT ANALYST'S MANUAL
Michael A. Dloogatch
Donald H. Schiller
January 1977

SECTION 2

GENERAL DESCRIPTION OF PACAM IV

PACAM IV has been developed from a series of earlier versions by an evolutionary process, and a convenient way to describe the features of the present system is to describe this evolution.

PACAM I was originally prepared for ASD/XR commencing in 1968, and was designed to simulate one-vs-one aerial combat in three dimensional space. Both sides used the same tactics, i.e., always aggressive. A limited maneuver suite was available, and each aircraft fought unaware of weapon usage by his foe. The resulting flight path data for the two aircraft were stored on tape to permit the subsequent evaluation of weapon firing opportunities. Under the auspices of ADTC/XR the evaluation program was expanded to include the flyout of missiles against the stored flight path of the target aircraft. An analytic evaluation of the end results was also provided. PACAM I was then utilized as a system of three separate models: Model B (duel), Model E (weapons) and Model D (end game).

In order to overcome some of the limitations in the PACAM I system and to provide a model more useful for the aerial missile program at Eglin AFB, the development of PACAM II was started. Although the program was completely rewritten for efficient operation and ease of input, the major thrust was in the area of tactics. Asymmetric tactics were permitted in that each

side was allowed different decisions under various conditions and the level of aggressiveness was incorporated. Nonaggressive (escape) tactics by reason of position, as well as for low fuel conditions were included. The simplistic decision process is based on tables supplied by the user which makes it easy to incorporate additional tactics. Finally, and most significantly, the model was designed to permit multi-aircraft combat, and several tactical routines were developed for this purpose. These tactical routines, and the user-supplied decision tables necessary to implement them are described in the PACAM II User's Manual.

Pacam II still utilized the partitioned model concept (B,E,D), which implies that maneuvering, both offensive and defensive, is independent of weapon firing. This limitation, plus a number of additional requirements leveled by various users was the impetus for the construction of the present version, namely PACAM IV.

The principal thrust of PACAM IV development was to permit dynamic reaction to weapons firing, with all the concomitant effects. In order to accomplish this goal, it was necessary to merge the three models described above (duel, weapons, end game) into a single program and provide additional subroutines to allow their interaction. First, the screening program was incorporated into the duel programs so as to evaluate firing opportunities for each of four weapon types (two missile types,

lasers, guns) on each aircraft at each time pulse. Optional firing doctrines then permit the choice of firing at first opportunity, or waiting if conditions are predicted to be improving.

For the case of missiles, a launch routine enters the missile into a list of active vehicles. Its path is then integrated along with the aircraft, so long as the missile remains viable. Presently, up to ten vehicles (aircraft and missiles) may be handled at one time. Weight and drag are decremented from the launching aircraft. If the missile is detected, the target aircraft may choose to evade the missile, changing the subsequent course of the battle. The program also contains a missile evaluation routine, which checks at each time pulse for break lock and/or closest approach to target. An end game routine determines whether or not a kill has been made. If so, the target is removed, aircraft roles are reassigned, and combat continued in a manner different than before. Similar dynamic evaluation is provided for gun and laser weapons, if present on the aircraft.

These dynamic weapons provisions, plus the desire by the LEAPS office at Kirtland AFB to use PACAM for bomber defense evaluation, led to another series of changes. First, size variations (from B-52 down to AIM-9) required that detection range be made a function of target size and aspect, as well as type of sensor. Second, this size variation, plus the requirement

for a smaller time pulse during missile flyout, led to a requirement for vehicle response rate limitations (roll, pitch, thrust) which effectively permit simulation of 5 DOF movement.

The concepts of kill evaluation, and action based upon missile detection led to requests for a stochastic determination of these variables, and this is provided in PACAM IV by an optional Monte-Carlo routine.

Finally, bomber penetration and defense tactics are available, together with tail defense weapon screening, firing and evaluation. (Fighter tactics against the bomber were well handled within the framework of the existing tactical routines.)

Evolution of the program has been accompanied by evolution of the display modes, progressing through the plotted output shown in the User's Manual to integral color movie preparation, as provided by the Computer Center at Kirtland AFB.

PACAM IV is written in FORTRAN IV, and comprises some 60 subroutines. Versions of the PACAM programs are presently operational at the following locations: Eglin AFB, Kirtland AFB, Wright-Patterson AFB, China Lake NWC and RAE Farnsborough.

SECTION 3

MODEL PROGRAM CHANGES

In order to accomplish the objectives of the PACAM IV work statement, every subroutine was subject to scrutiny; many were revised or eliminated. This section is organized to group all of the present and past subroutines into four categories:

1. Those unchanged in name and function, even though minor modification may have been required.

2. Those changed in name, but not in function. This group includes routines utilized in the Weapons Evaluation Routine (Model E) and incorporated into the consolidated model (PACAM IV).

3. Subroutines no longer required in the restructured program.

4. Subroutines added into the program to accomplish the consolidation of Models B and E, and to fulfill the other objectives of the program.

Each of the four categories will be discussed below, with major emphasis on the subroutines that are new to the program.

3.1 SUBROUTINES FUNCTIONALLY UNCHANGED

Thirty-seven subroutines, either from Program B (Aircraft

Engagement) or Program E (Weapon Evaluation) have been retained in the consolidated version, and are listed in Figure 1.

In each case, the logic, purpose and mathematics as described in the PACAM II Analyst's Manual remain unchanged, although almost all underwent some minor rewriting.

Examples: 1) Input routines (ACIN and MSLIN) are revised to include new variables required, such as roll rate and size factor. 2) The line-of-sight routine (LOS) and information status (INFORM) now compute values for missile-aircraft pairs, where applicable. 3) Subroutine CHOICE performs the same function as before, "utilizing the aircrafts's actual engine and aerodynamic input data to limit performance to that available." However, the subroutine was completely rewritten to include the effects of roll rate, pitch rate and thrust rate in limiting performance.

3.2 SUBROUTINES WITH NAME CHANGES

Seven subroutines from the Weapons Evaluation Program (Model E) have been incorporated into the consolidated model, with new names to eliminate coding interferences. These are listed in Figure 2 with the old name as described in Section 4 of the PACAM II Analyst's Manual, together with the new nomenclature. Each has been subject to a rewrite, similar to that described above, but with no change in function or logic. VALUE1 AND VALUE2 from Model E have been combined.

Finally the old calling programs, PACAMB AND PACAME now exist as PACAM4.

3.3 SUBROUTINES DELETED

The consolidation of programs has eliminated the need for seventeen subroutines from the program, as listed in Figure 3.

In general, this elimination was occasioned by one of three reasons.

1. The function performed by the routine was already being performed elsewhere, e.g., integration for all vehicles can be handled by INTGRT, eliminating the need for MSLING.

2. There is no longer a need for the function. The dynamic weapons launch, flyout and target reaction capabilities eliminate the need for a "canned" target path (PTPIN and TGTING).

3. Efficiency of programming, e.g., the PACAM II Analyst's Manual states in Section 4.5.2 that the single subroutine (TRANS) in Program B performs the same function as three subroutines (MAT1, MAT2, MATMUL) do for Program E. Since TRANS is available in PACAM IV the others may be eliminated.

Finally, the entire program concerned with survival probability (Model D) is eliminated, since this analysis is performed on a dynamic basis in the consolidated program.

3.4 NEW SUBROUTINES

Thirty-one new subroutines were required to complete the development of PACAM IV, and these are listed in Figure 4.

Three of the subroutines (INITL, MINESP, and LAZQWT) were designed by personnel of the LEAPS office at Kirtland Air Base. These are concerned with the input of laser parameters, calculation of laser fluence, and evaluation of laser damage against aircraft and missiles, respectively. These three subroutines are described in a classified supplement, along with the laser input values referred to in section 3.2.3 of the User's Manual.

The remaining twenty-eight routines are described below, listed in alphabetical order. If a routine implements a maneuver state, this information will be incorporated in the title.

The majority of these new routines are required for input/output, maneuver implementation or data manipulation and are not concerned with descision type of logic. Just two new routines:

BATMAN: for battle management

FIRE; for holding fire

are of this type, and logical flow diagrams for each accompany their description.

3.4.1 SUBROUTINE APPRCH (Maneuver state 86)

This routine defines a missile maneuver, called when seeker lock is broken or when the missile has closed to within seeker saturation range of its target. The path is a straight line with the bearing and elevation equal to values existing when target information was last available.

3.4.2 SUBROUTINE BARREL (Maneuver state 18)

This routine is used to implement an aircraft maneuver in which the aircraft follows a helical rolling path with a specified period and gee loading. This maneuver may be used as any entry in the decision table for free-engaged or double attack tactics.

3.4.3 SUBROUTINE BATMAN

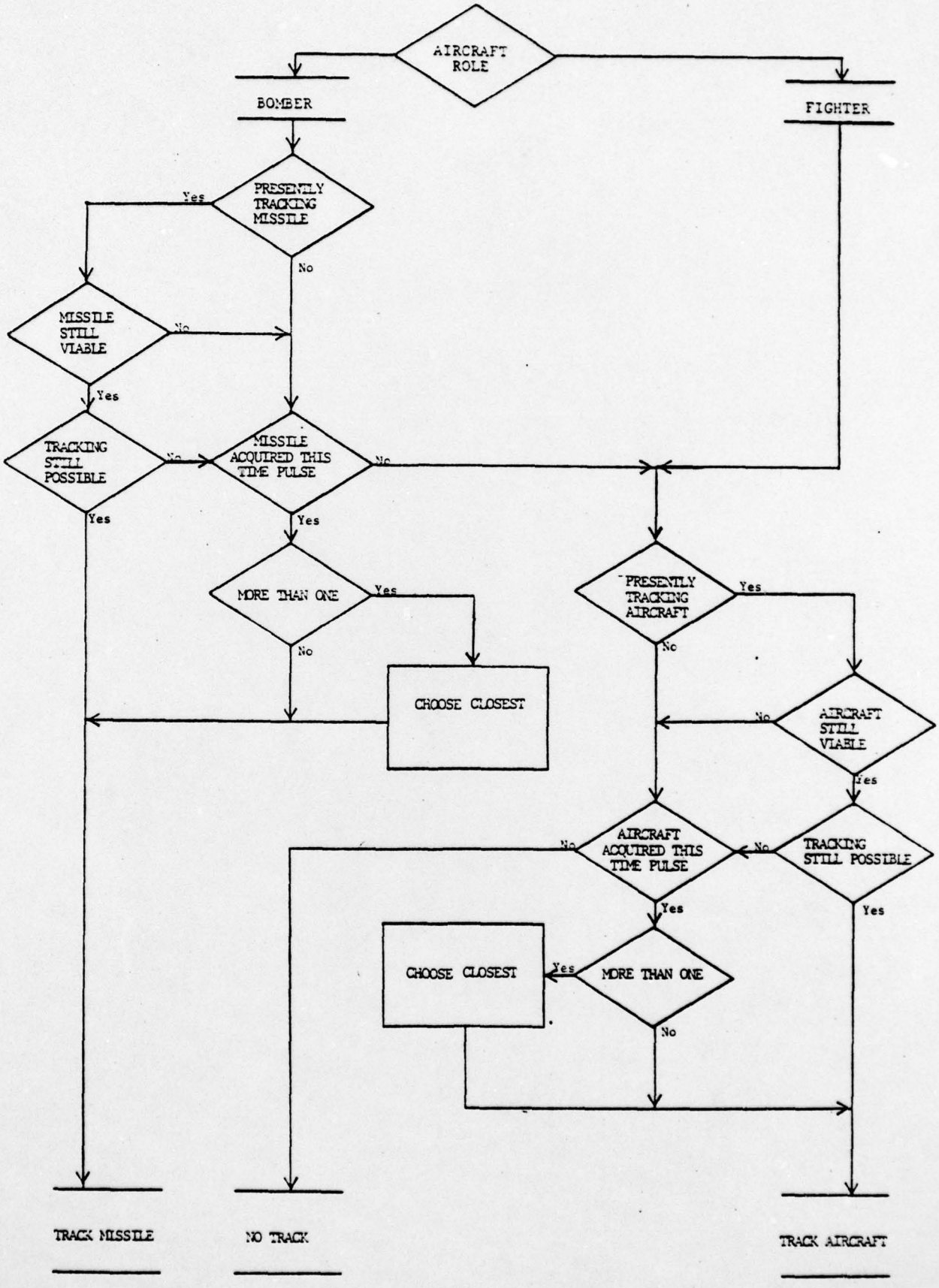
Battle management (BATMAN) is provided in this routine for those cases where aircraft have multiple target possibilities (aircraft and/or missiles).

Targets are evaluated on a priority basis to determine which one should be tracked and screened for weapon firing opportunities.

3.4.4 SUBROUTINE BINGO (Maneuver state 12)

This routine combines the common portions of the DZ3R and DZ4R into a single routine, as flow diagrammed on page 3 - 35 of the PACAM II User's Manual. It provides for the escape maneuvers which are used when an aircraft runs its fuel down to the Bingo level.

ENGAGEMENT DESCISION LOGIC
PORTION OF
SUBROUTINE BATMAN



3.4.5 SUBROUTINE BOMDEF (Maneuver state 19)

This subroutine implements the maneuver to be performed by a bomber with a tail defense weapon, when its opponent is in the bomber's defense zone. This maneuver consists of attempting to keep the target at the bearing angle most conducive to tail defense weapon firing.

3.4.6 SUBROUTINE DISENG (Maneuver state 13)

This maneuver subroutine directs an aircraft to a heading directly opposite that being flown at the time of instigation. It is normally called as a result of laser action by bomber aircraft, but can be used for any other reason of disengagement.

3.4.7 SUBROUTINE ENDGAM

At the time of aircraft destruction, missile destruction, or closest approach, this routine removes all dead bodies, turns off all sensors to (or from) such vehicles, calls for role reassignment (RASGN4) when necessary, and generally cleans up.

3.4.8 SUBROUTINE EVADE (Maneuver state 11)

This aircraft maneuver subroutine directs the plane into a maximum gee turn to avoid a missile, following detection. (This routine is particularly significant in that it provides dynamic response to missile firing, just as DISENG provides response to laser operation).

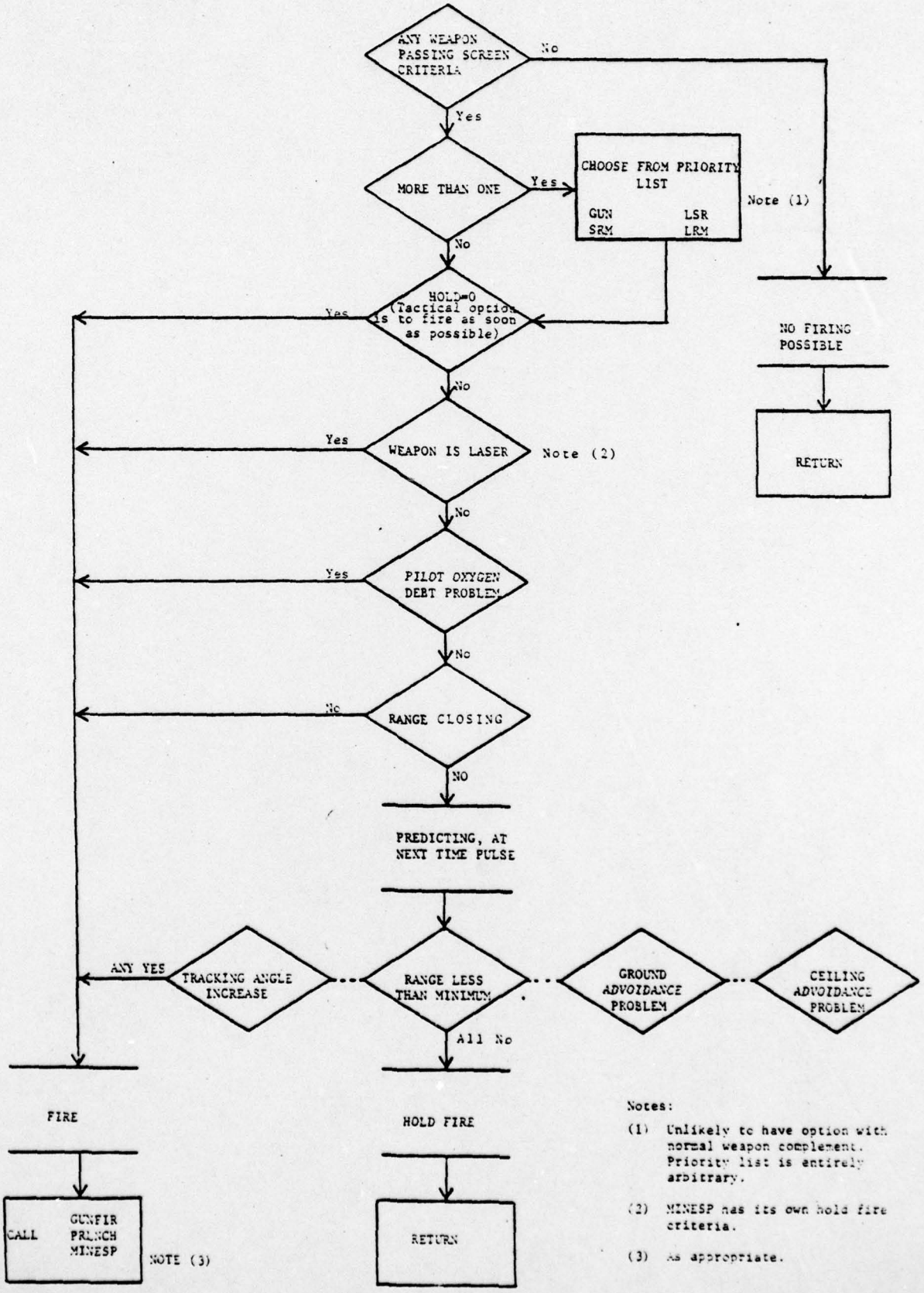
3.4.9 SUBROUTINE FIRE

This routine chooses between those weapons on board an aircraft that can be fired at a particular time, subject to additional physical constraints. Included are availability of weapon, time between firing and number in air at the same time. When all criteria are satisfied, firing is instigated. For missiles and guns, the option to fire now, or hold if conditions are predicted to be better at the next time pulse, is available.

3.4.10 SUBROUTINE GUNFIR

This subroutine, called when appropriate by FIRE (above), initializes the start of a rapid fire gun burst.

THE FIRING DESCISION PROCESS
(PORTION OF SUBROUTINE FIRE)



Notes:

(1) Unlikely to have option with normal weapon complement. Priority list is entirely arbitrary.

(2) MINESP has its own hold fire criteria.

(3) As appropriate.

3.4.11 SUBROUTINE GUNQWT

This subroutine performs the same function as MSLQWT does for missiles, and LAZQWT for lasers, i.e., determines the result of the weapon usage. At each time pulse, the angle between the gun line and the desired pointing vector is computed, and the number of hits is accumulated. At the end of the burst, kill probability is computed, based on the ratio of hits/rounds fired.

3.4.12 SUBROUTINE KILVAL

This routine computes the probability of kill of an aircraft by a missile by comparing lethal radius of the missile to closest approach distance.

3.4.13 SUBROUTINE LAUNCH

This routine initializes all of the missile data (coordinates, velocity components, etc.) at the time the missile separates from the aircraft. Also the aircraft weight, drag and weapons complement are decremented.

3.4.14 SUBROUTINE MCDET

Through this routine, the option to utilize a Monte-Carlo detection process (rather than deterministic) is provided. Called from Subroutine INFORM, range is compared to a computed nominal range, and a probability of detection determined from an exponential distribution, In particular:

$$P_D = e^{a(R/RNOM)^4}, \quad a = \ln(.5)$$

Nominal range (RNOM) is computed for each sensor in Subroutine RFIND, described below.

3.4.15 SUBROUTINE MPURST (Maneuver state 85)

This routine allows the user the option of a pursuit course missile guidance system. The method used is exactly the same as used in Subroutine PURSUT (for aircraft).

3.5.16 SUBROUTINE OUT3

This is an output routine providing the results of the weapons screening program. An example of the output generated by this program is displayed on page 83 of the User's Manual.

3.4.17 SUBROUTINE OUT7

This output routine generates the detailed report described in Section 4.3.4 (page 85) of the User's Manual.

3.4.18 SUBROUTINE OUTT

This subroutine consists of the tape output section, formerly an integral part of OUT1, and described in the PACAM II User's Manual. This seperation was made since the consolidated program does not need this intermediate tape output, except as an input to the Eglin AFB movie preparation program.

3.4.19 SUBROUTINE OUTSUM

As an alternate to, or in addition to, the normal detailed reports provided in a PACAM IV run, this routine gives the option to list only significant events occuring during the duel. Section

4.3.6 (page 92) of the User's Manual gives an example.

3.4.20 SUBROUTINE PACED

In order to provide input for the graphics and movie packages available at Kirtland AFB, this subroutine has been written to reorder, format and redimension the flight path data and aircraft orientation, as required.

3.4.21 SUBROUTINE PENTRT (Maneuver state 20)

This subroutine directs a bomber which is not being attacked via a check point, to the target. If attack occurs prior to reaching the check point, the bomber will proceed directly to target when free.

3.4.22 SUBROUTINE PRLNCH (Maneuver state 81)

This subroutine, called by FIRE, sets up a missile identification and target assignment, and computes the time between firing initiation and departure from the launching aircraft.

3.4.23 SUBROUTINE PRONAV (Maneuver states 83, 84)

This subroutine provides for a missile flying a proportional navigation course to the target. (Equations are given in the PACAM II Analyst's Manual, p. 4-19). The proportionality constants may be single valued, or double valued with a range change-over point. In this latter case, maneuver state designation also changes at that point, i.e., from 83 to 84.

3.4.24 SUBROUTINE RATES

This subroutine takes the values which have been read in for roll, pitch and thrust rates and corrects them to the necessary form to be used in limiting aircraft performance.

3.4.25 SUBROUTINE REACT

This subroutine surveys each aircraft to determine if it is under missile attack, and is capable of reacting. (If already avoiding an earlier missile, it will continue to do so until no longer necessary). If so, an evade signal is set and maneuver state 11 will be requested by the REVACT (Review Action) subroutine.

3.4.26 SUBROUTINE REMOVE

This subroutine provides the necessary "housekeeping" functions to remove a missile from the program storage, and updates the appropriate counters (e.g., number of missiles in air).

3.4.27 SUBROUTINE RFIND

This subroutine computes the nominal detection range (RNOM) referred to in Section 3.4.13. This range is based upon the size of the target, its aspect, type and power, and upon the power of the sensor being used. Use is made of the detection contours described in the User's Manual Section 3.2.6.

3.4.28 SUBROUTINE RNGREQ

This routine is used to establish maximum and minimum firing ranges for missiles, based upon performance limitations as opposed to those based upon detection criteria which are used in the subroutine SCREEN.

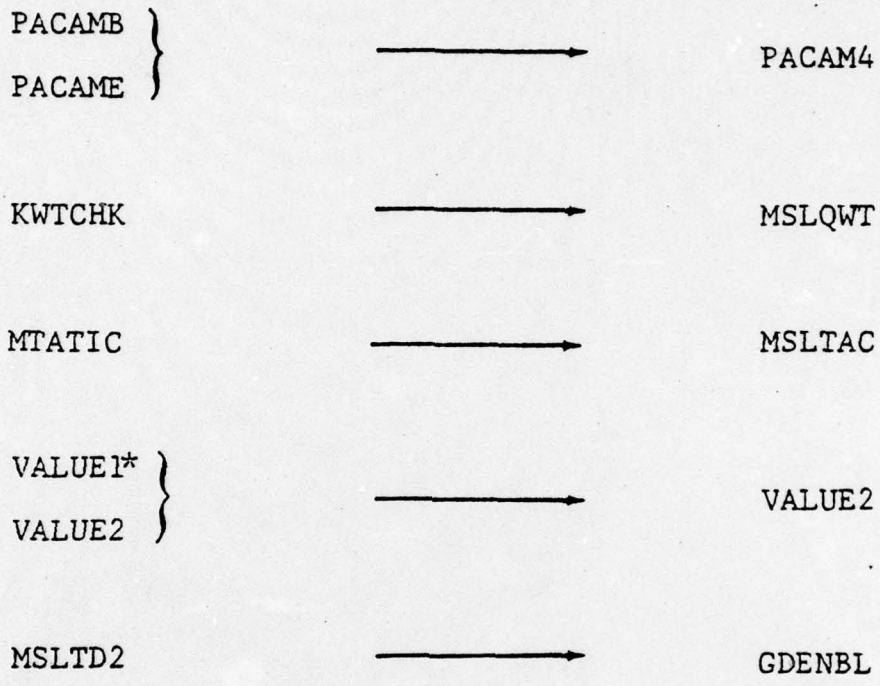
FIGURE 1

PACAM IV SUBROUTINES RETAINED FROM PACAM II

ACIN	OUT1
ACTION4	OXDEBT
ASIGN4	PERFORM
BRKT	POSTUR
CHANDL	PURSUT
CHOICE	RASGN4
DZ1R	REVACT
DZ2R	SCREEN
DZ3R	SCRNIN
DZ4R	STRESG
FORMA	TABIN
INFORM	TACIN
INITIA	TACPAC
INTGRT	TIMFLT
LOOP	TRANS
LOS	UNAWAR
MSLIN	VALUE1
OFFENS	VALUE3
	VSOLV

FIGURE 2

PACAM IV SUBROUTINES DERIVED FROM THOSE IN PACAM II



*There were VALUE1 routines in both the B and E programs. The one referred to here is from the E program.

FIGURE 3

PACAM II SUBROUTINES DELETED
FROM PACAM IV

AZEL

BTPIN

DADEF

DEFENS

EOUT

FLYOUT

INTRPT

LOSCAL

LNPRNT

MAERO

MAT1

MAT2

MATMUL

MSLING

MSLTD1

OUT2

TERM

TGTING

VALUE4

VALUE5

FIGURE 4

NEW ROUTINES DEVELOPED
FOR PACAM IV

INITL		LAUNCH	
LAZQWT		MCDET	
MINESP		MPURST	(MS 85)
		OUT3	
APPRCH	(MS 86)	OUT7	
BARREL	(MS 18)	OUTSUM	
BATMAN		OUTT	
BINGO	(MS 12)	PACED	
BOMDEF	(MS 19)	PENTRT	(MS 20)
DISENG	(MS 13)	PRLNCH	(MS 81)
ENDGAM		PRONAV	
EVADE	(MS 11)	RFIND	(MS 83,84)
FIRE		RATES	
GUNFIR		REACT	
GUNQWT		REMOVE	
KILVAL		RNGREQ	